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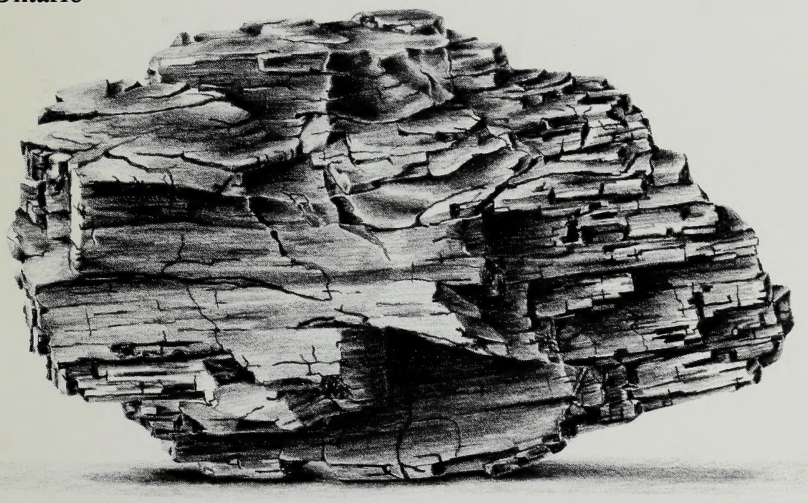
Recent Studies of Coal Mining, Cleaning and Upgrading

Projects supported in part by the Alberta/Canada Energy Resources Research Fund and the Action Committee on Western Canadian Low-Sulphur Coal to Ontario



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The contents of this publication are based on the information and data obtained from, and the results and conclusions of, research projects conducted by independent researchers with financial assistance from either the Alberta/Canada Energy Resources Research Fund or the Action Committee on Western Canadian Low-Sulphur Coal to Ontario.

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Foreword

Beginning in 1976, numerous projects were initiated in Alberta by industry and academic research institutions to help make better use of Alberta's energy resources.

Most of these research, development and demonstration efforts were funded by the Alberta/Canada Energy Resources Research Fund (A/CERRF), which was established as a result of the 1974 agreement on oil prices between the federal government and the oil-producing provinces.

Responsibility for applying and administering the fund rested with the A/CERRF Committee, made up of senior Alberta and federal government officials.

A/CERRF program priorities focused primarily on coal, energy conservation and renewable energy, and conventional energy resources. In 1988/89, a hydrogen research component was added.

Administration for the A/CERRF program was provided by staff within the Research and Technology Branch of Alberta Energy.

In recognition of the importance of coal to Alberta's economy, the Alberta Office of Coal Research and Technology was established in 1984 within Alberta Energy and Natural Resources (now Alberta Energy). Its primary purpose is to encourage the development and application of new technologies related to Alberta coals.

In 1987, the Action Committee on Western Canadian Low-Sulphur Coal to Ontario was established. It comprises the Deputy Prime Minister and the premiers of British Columbia, Alberta, Saskatchewan and Ontario. The purpose of the Committee is to foster greater use of western Canadian coal in Ontario. This would provide social and economic benefits in both Ontario and western Canada, and substantially improve the air quality associated with coal-burning in Ontario. The research program of the Committee is administered by an Intergovernmental Secretariat whose members represent all the participating governments.

The Alberta Office of Coal Research and Technology is the agency through which funding contributions by the Government of Alberta and A/CERRF are provided to coal research and development projects in industry, academic institutions and other research establishments. As part of its mandate, the Office monitors the progress of these research projects in an overall program designed to improve the production, transportation and marketability of Alberta coals.

The A/CERRF program ended on March 31, 1991, and the support it provided has been replaced by funding from the Alberta government.

A series of technology transfer booklets, begun in 1986 with A/CERRF support, continues to make research results available to industry and others who can use the information. This service will continue until all A/CERRF projects have been described.

For more information about other publications in the series, please refer to page 13.

For more information about the program to encourage greater use of western Canadian coal in Ontario, contact:

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Recent Studies of Coal Mining, Cleaning and Upgrading

Introduction

In a world coal market characterized by considerable competition, depressed prices and emerging coal-use technologies, it is recognized that Alberta coal companies must find ways to remain competitive. To do this, they must mine and prepare coal more efficiently for a market that is becoming increasingly sophisticated. It is clear that coal consumers have become more demanding about product consistency in terms of combustion characteristics, ash production and the formation of air pollutants. To satisfy these demands, techniques for removing non-combustible mineral matter and moisture in coals are constantly being improved. This not only allows producers to supply higher quality coals, but also minimizes the costs of shipping non-combustible substances having no economic value.

Although washing continues to be the most common coal preparation method, in Alberta it generates substantial quantities of tailings from the clays and fines associated with Alberta coals. These tailings represent lost product and require large storage lagoons as an environmental protection measure. Therefore, alternatives to current washing techniques are needed.

Also, as modern fuel standards have become more stringent in response to the availability of new or improved combustion technologies, coal researchers world-wide have begun to develop methods to upgrade coal into products that have been energy-enhanced or which produce fewer nitrogen and sulphur oxides when burned.

A broad range of research investigations covering all these issues is being pursued in Alberta, particularly those studies aimed at upgrading bituminous and subbituminous coals to enhance their energy content and combustion performance characteristics, and to recover more fines in the form of economically valuable products.

Some of these research projects were funded in part by the Alberta/Canada Energy Resources Research Fund (A/CERRF), while others received support from the provincial and federal government participants in the Action Committee on Western Canadian Low-Sulphur Coal to Ontario. The Government of Alberta is a member of this committee, and Alberta's financial contributions are made from the Alberta Heritage Savings Trust Fund.

The results of this research are reported here. Earlier studies were described in 1988 and 1989 in the technology transfer publications, *Development of an Agglomeration Process to Beneficiate and Transport Alberta Coals; Coal Preparation Research in Alberta;* and *Studies of Fine Coal Cleaning and Upgrading Processes for Alberta Coals.*

Automated Machine Control for Optimized Mining (AMCOM)

In 1987/88, a detailed review was made by the Coal Mining Research Company of non-cable vehicle guidance systems that might be used in Alberta's coal industry, and might also provide an opportunity to manufacture new products, thereby diversifying Alberta's economy.

In this project, some of the reviewed technologies included systems based on inertial guidance, dead reckoning, radar, laser beacons, ultrasonics, machine vision and radio frequencies.

The most promising systems were investigated in terms of range, accuracy, flexibility, reliability and costs. Plans were developed for constructing a single prototype and testing it under local mining conditions. This project was described in 1989 in the technology transfer booklet, *Advanced Coal Mining Techniques for Alberta.*

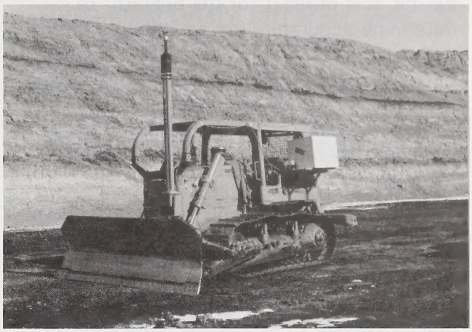
Experience gained from this project led to the development of an improved dragline monitor and an automated machine control system for selectively mining coal adjacent to partings and waste material.

The latter device, known as Automated Machine Control for Optimized Mining (AMCOM), is intended to help reduce the amount of coal lost, and the amount of foreign material introduced, when mining occurs at coal/waste interfaces. In some mining operations, for example, more than 10 per cent of the total coal reserves are lost in this manner. In other cases, excessive amounts of foreign material are mixed with coal. This causes problems in power plant boilers and preparation plants.

The AMCOM design comprises four modules, each of which uses proven, off-the-shelf components. The four modules are:

- a coal quality sensing module;
- a computing/lithology-mapping module;
- a navigation/vehicle-position tracking module; and
- a machine control module.

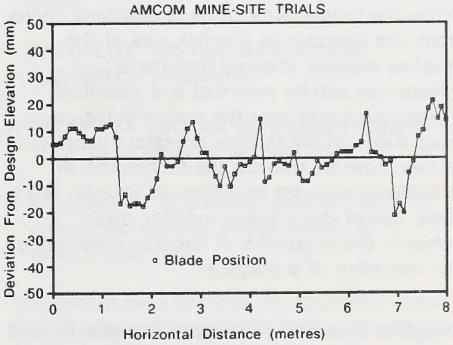
During 1988/89, all four modules were developed and installed on a Bobcat loader for initial field testing. The test showed that the AMCOM could control the elevation of the Bobcat bucket within 10 mm of the required position. Subsequently, the system was installed on a bulldozer and tested at a coal mine. Here, the system provided a reliable electronic map of the elevation of the coal/waste contact in the working area, and the control strategy employed by AMCOM provided the required control precision. Also, the AMCOM operated satisfactorily during adverse weather conditions.



AMCOM, installed on a bulldozer, was used in mine-site tests.

(Photo courtesy of Coal Mining Research Company)

Precision Of Blade Elevation Control



Standard Deviation of Control Error = 9.6 mm

(Source: Automated Machine Control For Optimized Mining, Daugela, G.C., B.G. Hollingshead, G.L. Hoffman and R.A. Wilson, Coal Mining Research Company, 1989)

Dragline Operations Monitor

The second project evolving from the non-cable vehicle guidance project, and carried out by the Coal Mining Research Company, was the development of a dragline monitor to help improve the efficiency of dragline operation and reduce mining costs.

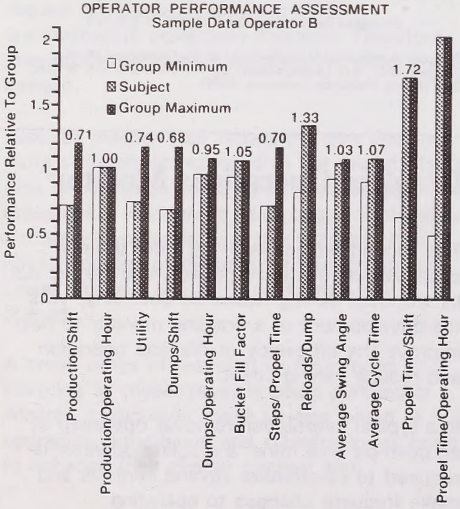
In a typical overburden-removal operation at an open-pit coal mine, a dragline operator is required to co-ordinate several controls and make frequent changes to operating techniques. Without some form of measuring

device, it is difficult for the operator to determine accurately the advantages of one technique over another. A dragline monitor, however, can record information quantifying the performance of the dragline in various operational modes and the performance of individual operators as they use different techniques.

In this project, an existing dragline monitor was obtained from Interactive Sciences Inc. in the U.S.A., and modified to record various machine functions. The modifications were made primarily to assure the generation of confidential information, but other alterations were made to accommodate the requirements of western Canadian coal mine operators.

Actual data from a U.S. coal mine were used to demonstrate the monitor's capabilities. While the productivity of large draglines varies from one operator to another, use of the dragline monitor showed that these differences can be recorded and identified. It was concluded that the device could be used successfully to train operators because it allows them to emulate the techniques of individuals who are proficient at specific tasks. Also, use of the dragline monitor might enhance the prospects of partially automating the operation of a dragline.

Dragline Operations Monitor Sample Report



(Source: Dragline Operations Monitor, Daugela, G.C. and B.G. Hollingshead, Coal Mining Research Company, 1989)

WESTCOAL Separator

When coal and associated refuse are mined and processed, they break into smaller particles. Thus, it is impossible to avoid producing some fines and slimes, which are defined as being 1 mm x 0.1 mm and <0.1 mm in size, respectively. For western Canadian coals, the proportion of fines and slimes is typically twice that of coals from other coal-producing areas. Also, the refuse associated with western Canadian coals tends to be soft. Therefore, considerable effort and cost must be expended to clean the fines and slimes found with western Canadian coals.

The principal method for cleaning coal is gravimetric separation, while fines and slimes are commonly cleaned by froth flotation techniques. Because the relative density of coal is related to its non-carbonaceous, or ash, content, cleaning with gravimetric separation allows a desired ash content to be achieved when coal having a certain range of relative densities is recoverd from the process. For western Canadian coals, an accurate separation in the relative density range of 1.5 - 1.7 is often required.

Devices known as spiral separators are generating interest in western Canada because they can recover fine coal more accurately than other devices and are reputed to have stable operating characteristics. Thus far, however, the lowest "cut-point" range available is approximately 1.9 - 2.2. Therefore, to optimize production and satisfy out-of-province and export markets, the objective of a project undertaken by the Coal Mining Research Company was to design and develop a device, known as the WESTCOAL Separator, specifically for western coals. In particular, the device was intended to have an appropriate density "cut point" and a higher unit capacity.

Using an existing spiral separator that was in operation at the Obed Mountain coal mine, several modifications were made to the device and its operation. Some resulted in poorer performance, but eventually a combination of modifications was found that achieved the desired improvement in separation performance and resulted in a lower ash content in the recovered coal.

It was recommended that a patent be sought for the WESTCOAL Separator, and prospective manufacturers be approached regarding their interest in fabricating the device. A preliminary market survey showed that sufficient potential for use of such a device exists in North America to proceed with developing and producing this product. Because the mechanical and operating details are confidential, additional information about the WESTCOAL Separator is available from the Chairman of the Office of Coal Research and Technology.

Testing of ARCOFLUX 130

In a patented process of the ARCO Petroleum Products Company, coal is dried to less than its equilibrium moisture, and then cooled. This is followed by treatment with a roofing asphalt product called ARCOFLUX 130. The treated coal is reported to be dust-free, free flowing and more stable than untreated coal. To determine whether similar results would occur with Alberta coals, a study was carried out by the Coal Mining Research Company involving ARCOFLUX 130 as a potential deactivant to prevent thermally dried low-rank coals from combusting spontaneously.

Coals from the Obed Mountain, Highvale and Costello mines were dried in a Roto-Louvre Dryer to less than their equilibrium moisture content, the values being 8, 8 and 17 per cent, respectively. After cooling, the dried coals were treated by spraying with ARCOFLUX 130.

The stability of the treated coals with respect to spontaneous combustion and moisture sorption potential was determined and compared with the parent coals in a moist or dry, untreated state.

It was found that the dried coals, whether treated with ARCOFLUX 130 or not, were significantly more reactive than the comparable moist feed. Also, it was noted that the coals treated with ARCOFLUX 130 did not exhibit significantly improved stability or moisture sorption properties relative to the untreated dried coals.

Testing also showed the following:

- when applied at rates of two or three per cent, ARCOFLUX did not significantly reduce the oxygen absorption potential or the production of carbon monoxide and carbon dioxide by dried coal;
- at the same application rates, ARCOFLUX 130 did not reduce the equilibrium moisture content or moisture sorption potential of coals;
- ARCOFLUX 130 has excellent dust suppression properties;
- ARCOFLUX 130 can significantly reduce the flow characteristics of coal; and
- the presence of surface clays appeared to reduce the coating effectiveness of ARCOFLUX 130.

The project was financed by Obed Mountain Coal Company Limited, the federal Department of Western Economic Diversification, Saskatchewan Energy and Mines, Ontario Ministry of Energy and the Government of Alberta. Alberta's contribution was administered by the Office of Coal Research and Technology.

Particle Distribution in Slurry Flow Through Tees and Manifolds

Two-phase (solid/liquid) flow through a manifold is used commonly in industry to distribute solids to various processing units. This occurs in coal preparation plants as well. Because differences in inertia occur between the solid and liquid phases, the solids concentration is not always the same in

various branches of a manifold. This led University of Alberta researchers to conclude that a study was needed to determine the relationship between solids concentration in the branches and the main pipe, as well as determining the upstream operating conditions that can affect this relationship. The objective was to achieve equal distribution of solids in each branch.

In a project carried out at the University of Alberta, a closed-loop piping arrangement having a manifold with four branches and valves was used to control slurry flow through the branches. Isokinetic and conductivity probes were installed to measure solids concentration upstream and downstream of the branch tees. Initial experiments involving sand/water slurries were conducted, using three configurations of branches: upwards, sideways and downwards. Also, three grades of sand were used: fine, medium and coarse.

It was learned that for sand-water slurries, only the sideways branch orientation gave a uniform solids distribution for the medium and coarse ranges of particle sizes, whereas a uniform solids distribution was achieved for all three piping orientations when fine sand was used.

The laboratory data were used to develop a model of solids distribution in the branches of the manifold. This empirical model, which was used to predict the concentration of solids in each branch, was found to be accurate to within 15 per cent of laboratory observations. This is considered to be adequate for design purposes.

Experiments with polyvinyl chloride particles, having a specific density of 1.2, showed the solids distribution for all three orientations was equally satisfactory. This is significant because the density of polyvinyl chloride is a better approximation to that of coal than is sand, which has a specific gravity of 2.6.

HYDROSIZER for Fine Coal Recovery from Tailings

Coal-cleaning experience elsewhere has shown that the patented HYDROSIZER device effectively separates low-density, undesirable material from fine coal (0.55 mm x 0.1 mm) having specific gravity values of less than 1.5.

In this project, the device was tested for the first time on western Canadian coals. A pilot unit at the Obed Mountain coal mine was fed with a 1.2 mm x 0 mm raw coal slurry partially deslimed at 0.15 mm. Two full performance tests were undertaken over a range of cut points.

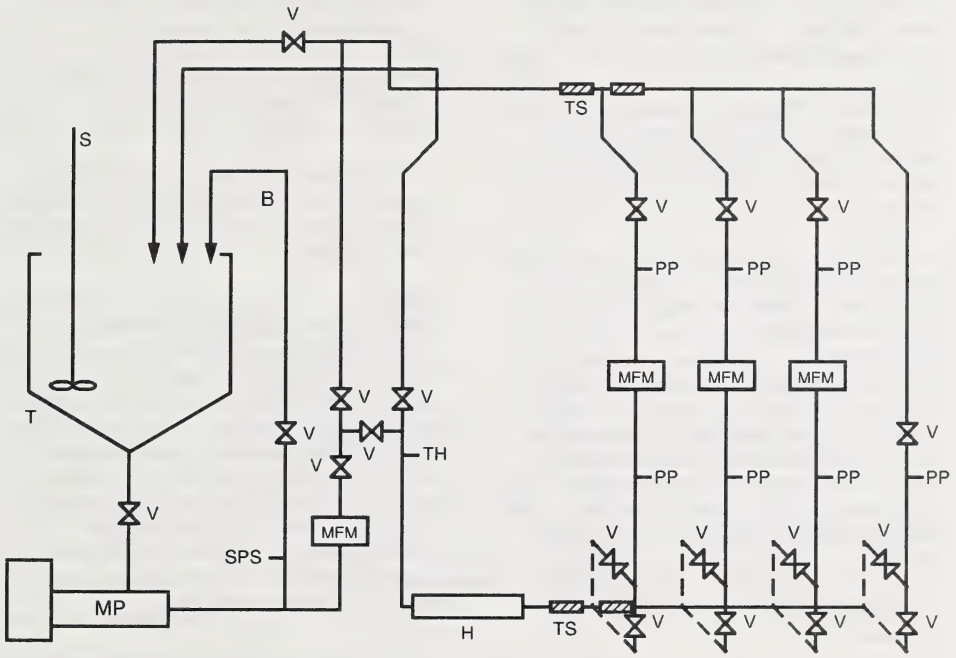
The performance was separately evaluated for the following 2:1 size fractions: 1.2 mm x 0.6 mm, 0.6 mm x 0.3 mm, and 0.3 mm x 0.15 mm. Mass and ash balances, and float-sink analyses, provided data for determining partition curves for each fraction.

Low cut points were achieved for material coarser than 0.6 mm, although the separations were not as sharp as those reported in the literature. Some suggestions were made to improve this performance. Products coarser than 0.3 mm met clean coal specifications for ash content. This result cannot be achieved by other devices using single-stage cleaning of this particular clay-contaminated thermal coal.

It was concluded that the HYDROSIZER can be a useful device in existing western Canadian coal preparation plants where a low or adjustable separation gravity is required.

The project was financed by Obed Mountain Coal Company Limited and the Government of Alberta, through the Office of Coal Research and Technology.

Experimental Arrangement for Study of Particle Distribution in Slurry Flow Through Tees and Manifolds



B	System Bypass Line	S	Stirrer
H	Double Pipe Heat Exchanger	T	Feed Tank
MFM	Foxboro Magnetic Flow Meter	TH	Thermometer
MP	Moyno Pump	TS	Transparent Section (Rotatable)
PP	Probe Port for Isokinetic Sampling	V	Valve
SPS	Safety Pressure Switch		

(Source: Particle Distibution in Slurry Flow Through Tees and Manifolds, Masliyah, J. and H. Nasr-El-Din, University of Alberta, 1991)

Coal Agglomeration Process Development

Beginning in 1980 with a study carried out jointly by scientists from the University of Alberta and Alberta Research Council, a method for agglomerating Alberta coals has evolved into a process having considerable commercial potential.

With initial funding from A/CERRF, and subsequent funding from the Electric Power Research Institute and other sources, research on this process has been conducted continuously over the past decade at the Alberta Research Council.

By mixing heavy oil or bitumen with coal slurries under controlled conditions, large particles called agglomerates are formed from which much of the undesirable mineral matter present in the original coal is removed and transferred to the water. This results in products having a higher energy content and lower ash than the parent coals from which they are derived.

Combustion testing has shown that agglomerates formed from subbituminous coals display excellent combustion characteristics. These results demonstrate that oil agglomeration is a promising upgrading method.

The early work on this process was described in 1988 in the technology transfer publication, *Development of an Agglomeration Process to Beneficiate and Transport Alberta Coals.* Subsequent developments are reported here.

The initial technology has evolved into two processes: AGLOFLOAT, which involves agglomeration followed by froth flotation; and AGFLOTHERM, which includes a thermal treatment step.

In 1987/88, a consortium[1] of 22 companies and institutions began to provide funding for a pilot-scale evaluation of the processes. Since then, a continuous 6-tonne-a-day (250 kg/h) pilot plant and a continuous oil recovery unit were built and made operational. Known as the Integrated Agglomeration Test Facility (IATF), the plant was used to evaluate the agglomeration potential of coal samples provided by members of the consortium, and to provide data to be used in calculating the process economics of a commercial-scale plant.

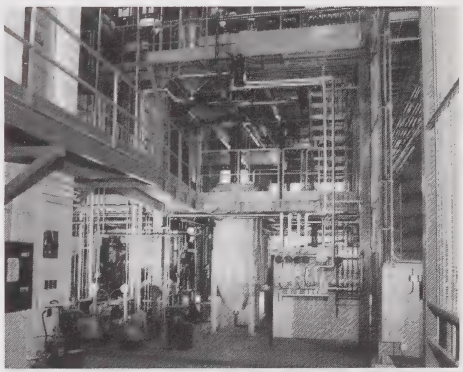
Test programs were carried out to do the following:

- beneficiate subbituminous coals with the use of high molecular weight hydrocarbons as binders;
- desulphurize bituminous coals; and
- recover hydrocarbons from oily wastes, tar refuse and contaminated soil.

The major steps in the coal agglomeration process are as follows:

- coal is crushed and fed to a mill, followed by the addition of water and further grinding;
- heavy oil is mixed with light oils to make an oil binder;
- the fine coal/water slurry and the oil binder are fed to another mixer where agglomerates are produced, and the clay and sand are transferred from the coal to the water slurry;
- the coal-oil agglomerates are separated from the sand by froth flotation, where air is bubbled through the slurry to push the agglomerates to the surface;
- the agglomerates are skimmed from the flotation step and are washed on vibrating screens to remove fine clay; and
- waste water from the froth flotation and screen-washing steps is treated in settling tanks to remove solid refuse, and then the water is reused.

Using the IATF, several investigations were carried out on behalf of the consortium members. The investigation of low-rank coals included: increasing the ability to separate mineral matter selectively; understanding the mechanisms responsible for high oil recovery during thermal treatment; the conceptual design of a 250 kg/h de-oiling system for coal/oil feed with a high API oil component; evaluation of the effects on process economics of improvements in selectivity and de-oiling; and process runs using low-rank coals from various sources.

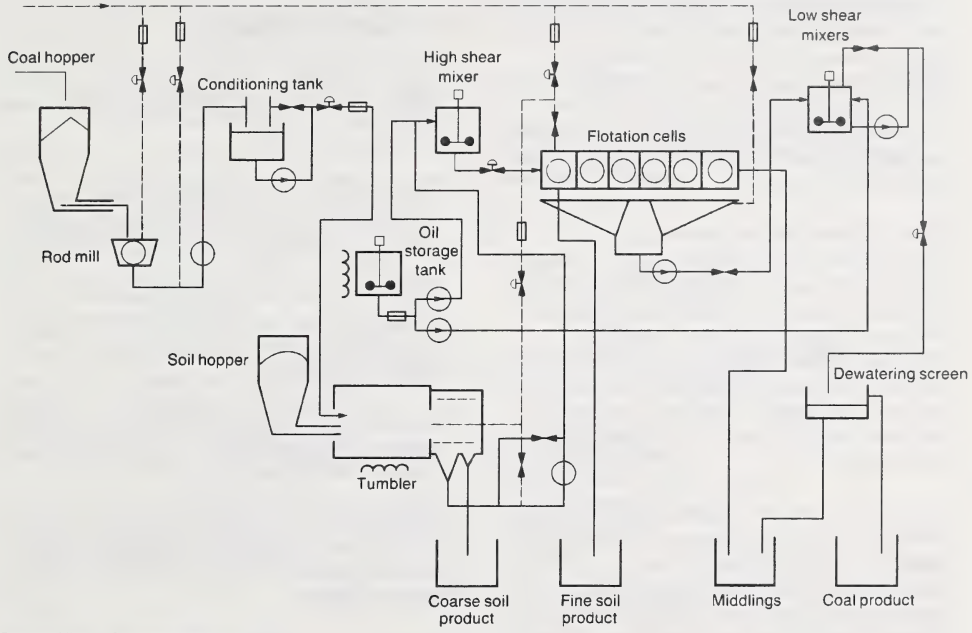


Integrated Agglomeration Test Facility used to beneficiate low-rank coals, desulphurize bituminous coals and recover hydrocarbons from contaminated soils.

(Photo courtesy of Alberta Research Council)

[1]The consortium includes: the Electric Power Research Institute, American utility companies, state and federal governments, Canadian oil firms, coal companies, provincial governments and utility companies.

Flow Diagram Of The 6 T/Day Continous Soil Clean-up Process At ARC Devon Facility



(Source: Alberta Research Council)

In the bituminous coal studies, batch evaluations were made of two-stage oil agglomeration on some eastern U.S. coals. In addition, the 250 kg/h agglomeration test facility was refined and tuned, and the performance of a continuous pyrite removal unit was tested on various coals.

The contaminated soil study included developing improved methods for cleaning coal-derived tar, slag and coke from soils, and conducting demonstration tests in the 250 kg/h continuous unit with refuse materials.

Final results from this work were presented to the consortium members at Palo Alto, California in February 1991.

Thermal Drying of Western Canadian Low-Rank Coals

Lignite and subbituminous coals from western Canada contain significant quantities of moisture. This reduces their heating value and lowers their competitive position relative to coals from other sources.

It has been proposed that removal of this moisture by thermal drying could upgrade these low-rank coals, thereby allowing their use in thermal power plants designed for higher rank coal. Also, removal of moisture should reduce the costs to transport these coals to markets in Ontario. The disadvantage of thermal drying is that dried coals are susceptible to spontaneous combustion.

Thus, in a project funded by industry and government and led by TransAlta Utilities Corporation, a subbituminous B coal from the Highvale mine, a high-volatile coal from the

Obed Mountain mine, and a lignite from the Costello mine in Saskatchewan were tested at the CANMET laboratories in Devon and at the Energy Research Unit of the University of Regina. The objective was to prepare a data base of thermal drying results to help determine the process limits and provide some indication of the economics of this approach to moisture removal.

Each coal was treated thermally at temperatures that varied from 200° to 400°C in three process media: nitrogen, steam and simulated products of combustion. Detailed analyses of each coal were carried out. Changes in coal properties as a function of thermal treatment temperature and process gas were interpreted in terms of changes in coal rank and the likelihood of combusting spontaneously.

It was found that the heating value of all three coals increased with temperature in the presence of all the gases. It was recommended that these coals should be heated above 300°C and below 400° to achieve a significant increase in heating value.

There was no loss of mineral matter or any measurable change in the mineral composition, but oxygen, oxygen-containing groups and volatile aliphatic carbon were all reduced.

The results regarding the susceptibility to spontaneous combustion were erratic, but it did appear that steam was marginally better at reducing this tendency.

This project was funded by TransAlta Utilities Corporation, Manalta Coal Ltd. and Esso Resources Canada Limited, as well as the Department of Western Economic Diversification and the governments of Alberta, Ontario and Saskatchewan through the Action Committee on Western Canadian Low-Sulphur Coal to Ontario. Alberta's contribution was administered by the Office of Coal Research and Technology.

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